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NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
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REPORT

ON

LAKE COLORADO CITY

MITCHELL COUNTY

TEXAS

EPA REGION VI

WORKING PAPER NO. 640

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

FEBRUARY, 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

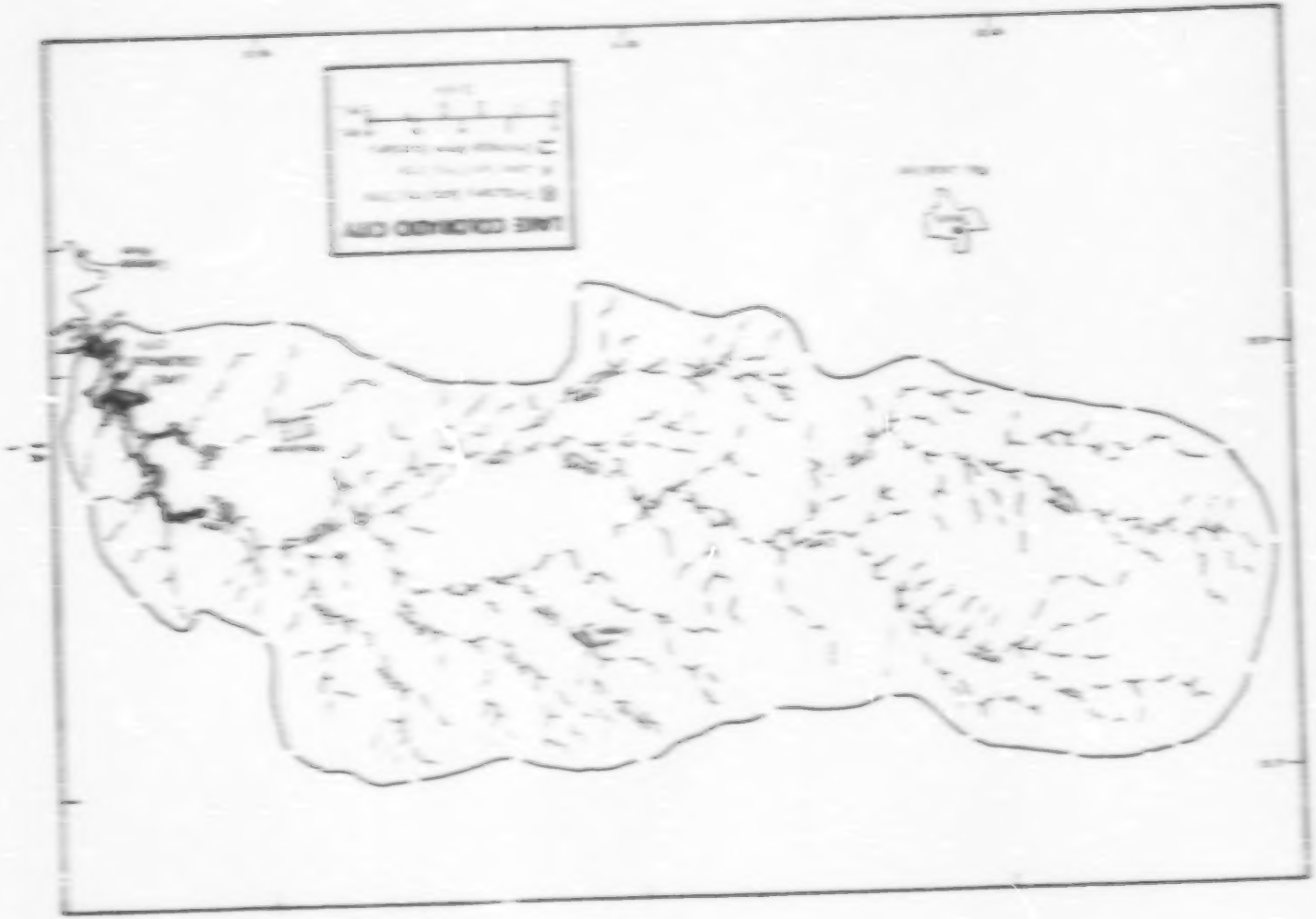
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass



LAKE COLORADO CITY

STORET NO. 4810

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Colorado City is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board, and there is little or no impairment of the designated beneficial uses of this lake.

Lake Colorado City ranked twentieth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters*. Twenty-two of the water bodies had less and two had the same median total and median dissolved phosphorus, eight had less and two had the same median inorganic nitrogen, 22 had less mean chlorophyll a, and 28 had greater mean Secchi disc transparency.

Survey limnologists did not observe algal blooms or macrophytes in the lake during sampling visits.

B. Rate-Limiting Nutrient:

The algal assay results indicate that nitrogen was limiting at the time the sample was taken (10/20/74).

The lake data indicate nitrogen limitation in March and October but phosphorus limitation in May.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted Lake Colorado City during the sampling year.

Septic tanks serving lakeshore dwellings are estimated to have contributed 8.3% of the total phosphorus load to the lake; however, a shoreline survey would be needed to determine the actual contributions of these sources.

The phosphorus loading of 0.21 g/m² measured during the sampling year is a little more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). Regardless of the applicability of Vollenweider's eutrophic level to Texas reservoirs, the lake is eutrophic, and all phosphorus inputs should be reduced to the greatest practicable degree.

2. Non-point sources--The phosphorus contributions of non-point sources, including precipitation, accounted for nearly 92% of the total load reaching the lake during the sampling year. Morgan Creek contributed 66.5%, Unnamed Stream 6-1 contributed 6.8%, and the ungaged drainage area was estimated to have contributed 10.1% of the total phosphorus load.

The phosphorus export rates of Morgan Creek and Unnamed Stream 6-1 were 1 and 4 kg/km²/yr, respectively (see page 11). These rates are quite low compared to the rate of a tributary to nearby Lake Stamford* (28 kg/km²/yr).

* Working Paper No. 660.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 6.52 kilometers²,

2. Mean depth: 6.0 meters,

3. Maximum depth: 18.2 meters,

4. Volume: 39,120 x 10^6 m^3,

5. Mean hydraulic retention time: 3.9 years (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Morgan Creek	704.7	0.282
Unnamed Stream B-1	26.4	0.011
Minor tributaries & immediate drainage -	91.4	0.043
Totals	827.5	0.336

2. Outlet -

Morgan Creek	834.0**	0.321

C. Precipitation***:

1. Year of sampling: 57.9 centimeters,

2. Mean annual: 50.0 centimeters.

† Table of metric conversions--Appendix B.
†† Latchford, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Lake Colorado City was sampled four times during 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the October visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 8.2 meters at station 1 and 4.9 meters at station 2.

The sampling results are presented in full in Appendix B and are summarized in the following table (the August nutrient samples were not preserved properly and were not analyzed).

[redacted]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	21.6 - 23.2	21.9	21.5
[illegible]	6.4 - 7.4	6.6	6.9
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	6.4 - 8.5	8.4	8.4
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[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	31.2 - 36.5	36.3	36.3
[illegible]	8.1 - 8.7	8.4	8.4

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/04/74	1. Diatoms sp.	2,160
	2. Oscillatoria sp.	2,014
	3. Flagellates	707
	4. Synedra sp.	545
	5. Dactylococcopsis sp.	336
	Other genera	1,972
	Total	7,804
05/15/74	1. Tetraedron sp.	3,283
	2. Chromonas sp.	1,082
	3. Diatoms sp.	830
	4. Scenedesmus sp.	722
	5. Oocystis sp.	721
	Other genera	3,102
	Total	9,740
08/06/74	1. Oscillatoria sp.	10,277
	2. Lyngbya sp.	3,755
	3. Nitzschia sp.	1,953
	4. Oocystis sp.	445
	5. Cryptomonas sp.	445
	Other genera	2,501
	Total	21,176
10/28/74	1. Oscillatoria sp.	8,779
	2. Nitzschia sp.	2,287
	3. Diatoms sp.	2,164
	4. Tetraedron sp.	1,266
	5. Lyngbya sp.	1,255
	Other genera	3,605
	Total	19,356

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/04/74	1	6.5
	2	6.4
05/15/74	1	7.6
	2	7.3
08/06/74	1	17.5
	2	19.4
10/28/74	1	18.2
	2	20.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.029	0.096	4.5
0.050 P	0.079	0.096	4.4
0.050 P + 1.0 N	0.079	1.096	28.2
1.0 N	0.029	1.096	8.4

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Lake Colorado City was moderately high when the sample was collected (10/28/74). There was no significant change in yield with the addition of orthophosphorus, but nitrogen added alone produced a yield significantly greater than that of the control. These results indicate that nitrogen was the limiting nutrient.

The lake data support the assay findings. The mean inorganic nitrogen/orthophosphorus ratio was 4/1 in October and was 7/1 in March, indicating nitrogen limitation. However, the N/P ratio in May was 21/1, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Morgan Creek at station A-2 and the mean annual ZZ flow.

No known municipal or industrial point sources impacted Lake Colorado City during the sampling year.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Morgan Creek	925	66.5
Unnamed Stream B-1	95	6.8
b. Mine tributaries & immediate drainage (non-point load) -	140	10.1
c. Known municipal STP's - None	-	-
d. Septic tanks* -	115	8.3
e. Known industrial - None	-	-
f. Direct precipitation** -	115	8.3
Total	1,390	100.0

2. Outputs -

Lake outlet - Morgan Creek 1,385

3. Net annual P accumulation - 5 kg.

* Estimate based on 400 lakeshore dwellings (Wyatt, 1976); see Working Paper No. 175.

** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Morgan Creek	12,325	47.5
Unnamed Stream B-1	475	1.8
b. Minor tributaries & immediate drainage (non-point load) -	1,880	7.2
c. Known municipal STP's - None	-	-
d. Septic tanks* -	4,265	16.4
e. Known industrial - None	-	-
f. Direct precipitation** -	7,060	27.1
Total	25,985	100.0

2. Outputs -

Lake outlet - Morgan Creek 16,620

3. Net annual N accumulation - 9,365 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Morgan Creek	1	17
Unnamed Stream B-1	4	16

* Estimate based on 400 lakeshore dwellings (Wyatt, 1976); see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic rutention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.21	< 0.01	4.0	1.4

Vollenweider phospherus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake Colorado City:

"Dangerous" (eutrophic loading)	0.20
"Permissible" (oligotrophic loading)	0.10

V. LITERATURE REVIEWED

Latchford, John B., Jr., 1974. Personal communication (lake morphometry). TX Water Qual. Bd., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Wyatt, Linda B., 1976. Personal communication (estimate of lakeshore dwellings). TX Water Qual. Bd., Austin.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN HANDBOOKS

LAKE CITE	LAKE NAME	[illegible] TOTAL *	[illegible] INDEX *	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] *
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LAKE DATA TO BE USED IN HYDROLOGY

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[illegible] OF LAKES WITH [illegible] VALUES [illegible] NUMBER OF LAKES WITH [illegible] VALUES

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] TOTAL N	[illegible] AREA KEC	[illegible] CHLA	[illegible] [illegible]	[illegible] [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] [illegible]

ROW	LAKE CODE	LAKE NAME	[illegible]
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]

[redacted] ranked by [redacted] No.

[redacted]	Lake Code	Lake Name	[redacted] No.
29	[redacted]	LYNDON B JOHNSON LAKE	239
30	[redacted]	TEXOMA LAKE	217
31	[redacted]	SOMERVILLE LAKE	203
32	[redacted]	SAN ANGELO RESERVOIR	200
33	[redacted]	TEXARKANA LAKE	179
34	[redacted]	GREEN LITTLE BLUE RESERVE	173
35	[redacted]	TRINIDAD	169
36	[redacted]	BRIANT LAKE	159
37	[redacted]	CORPUS CHRISTI LAKE	155
38	[redacted]	HOUSTON LAKE	139
39	[redacted]	LEWISVILLE LAKE	91

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

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APPENDIX D

PHYSICAL and CHEMICAL DATA

APPENDIX I

TRIBUTARY DATA

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best available copy.

[illegible]

[illegible]
[illegible]
[illegible]

STORET RETRIEVAL DATE 74/11/21

481101
32 21 58.0 180 50 28.0 4
ORANGE, STATE
48 ft LA COLA CITY
TAJAKE CALIFORNIA CITY
SET ON BRDG 2.5 MI E OF WESTWOOD
ESPALES ZONE
WELL FEET DEPTH CLASS 00

DATE	TIME	DEPTH	00630 NO2&NO3 TOT 0.45U	00625 TOT KJEL	00610 NH3-N	00671 PHOS-DIS	00665 PHOS-TOT
FROM	OF		MG/L	MG/L	MG/L	MG/L P	MG/L P
TO	DAY	FEET					
74/11/09	13	30	0.256	1.500	1.005	0.140	0.230
75/05/27	14	15	0.011	1.600	1.025	2.070	0.256
75/08/19	15	00	2.040	0.950	1.025	2.170	0.340